DEVELOPMENT OF A PNEUMATIC SPREADING SYSTEM FOR KEVLAR-BASED SiC-PRECURSOR CARBON FIBER TOWS

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Introduction

Silicon carbide (SiC) fibers have exceptional potential for use as support fibers in metal matrix composites (1). One method of obtaining these fibers is through chemical vapor deposition (CVD) onto a substrate fiber (2). Industrially, tungsten wire is used as the precursor material; however, tungsten is expensive and does not provide a smooth surface for deposition (3). For defense applications, the ideal precursor fiber should be inexpensive, have a small, uniform diameter, possess a coefficient of thermal expansion that is compatible with the SiC coating, be available from a reliable domestic supplier, and have sufficient tensile strength to withstand CVD processing.

The best solution to this problem may be to use a low cost, low modulus carbon fiber substrate. Although isotropic pitch fibers fit the above criteria, their poor tensile strength make rewinding prohibitively difficult. Fortunately, it has been shown that high-performance polymers such as PBO (poly p-phenylene benzobisoxazole) and Kevlar (poly p-phenylene terephthalamide) can be converted directly to low modulus, uniform diameter carbon fibers without stabilization (4, 5).

Carbonized Kevlar fibers have diameters of under seven microns, moduli of less than 150 GPa, and tensile strengths of approximately 1 GPa (6). Thus, the conversion system depicted in Figure 1 could be used to form SiC fibers directly from carbonized Kevlar. The only technical limitation inhibiting the use of carbonized Kevlar is the lack of an available monfilament. During the CVD process, each Kevlar-based carbon fiber filament must be unencumbered by its neighbors for long enough to receive the SiC coating. Without effective spreading, the effects of fiber bridging could become severe.

Experimental

This research focused on the design and manufacture of an effective pneumatic spreading system for Kevlar-based carbon fibers tows. High-speed photography was used to evaluate the effectiveness of the spreaders. Fiber diameters were measured using a laser diffraction technique (7). Gas flow rates were determined by measuring the exit velocity of the gas stream using an anemometer. Finally, tensile strengths and moduli of the fibers were measured using a modified Instron Ulitmate Testing Machine. All spreaders were constructed from commercial lucite.

Results and Discussion

A series of spreaders that focused on axial spreading effects were found to be the most effective. First, the tow is passed through an Axial Type I Venturi Spreader, shown in Figure 2. In this spreader, the inner channel widens, much like the nozzle of a venturi flow meter. The resultant venturi effect aligns the streamlines of the spreading gas in a favorable fashion. The divergent nozzle moves the tow through a pressure differential, resulting in a chaotic motion of filaments within the tow. At the same time, the venturi throat minimizes the formation of undesirable vortices and eddies.

At the opposite end of the spreading region, the tow is passed into an Axial Type II Venturi spreader. This device, pictured in Figure 3, is conceptually similar to the Type I spreader. However, the tow is fed into the spreader through a narrow hole drilled at a thirty degree angle to the channel and the gas inlet is positioned at the rear, rather than the middle, of the spreader. In this design, the entire gas flow could be biased to one end of the spreader only.

The tension required to advance the fiber along the towline had a tendency to reduce spreading. To alleviate this problem, a system of pinch rollers were constructed and used to create a loop of slack in which the spreading could occur. Fibers emerging from the carbonization step were pinched between rubberized rollers. Another pinch roller was placed beyond the last spreader before the traversing waywinder.

Using this system of pich rollers and venturi spreaders in series, a highly chaotic, three-dimensional spread was achieved and maintained through a linear distance of three feet. With gas velocities of 25 cfm, a chaotic spread with a total diameter of three to four inches was maintained across the entire three feet. Figure 4 shows a stop action photo of this spreading. It is important to note that the two-dimensional photograph cannot perfectly capture the entire three-dimensional nature of the spreading.

Conclusions

Significant spreading between individual fibers was achieved using the the axial venturi spreading system. Enough spreading is achieved to make CVD coating possible. This spreading can be maintained for a linear distance of three feet. The use of shallow rectangular channels prevents the vorticular twisting effects experienced in round channels. Finally, Kevlar-based carbon fibers seem to possess considerable potential as a silicon carbide precursor fiber.

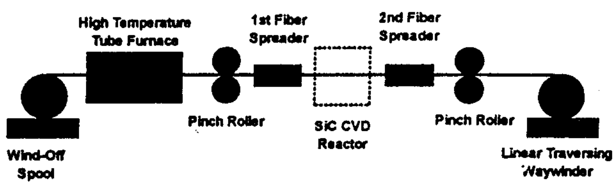

Figure 1. Spreading System Configuration

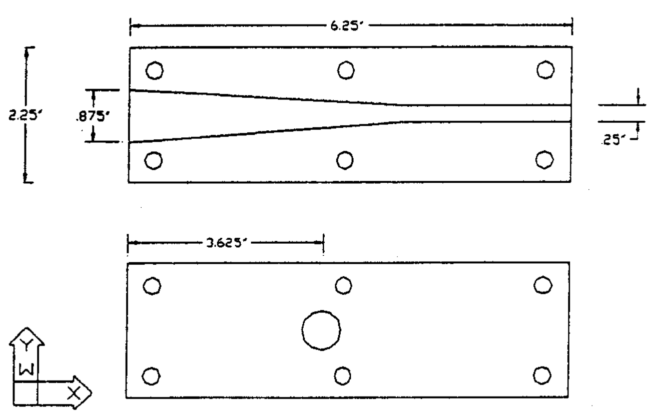

Figure 2. The Axial Venuri Type I Spreader

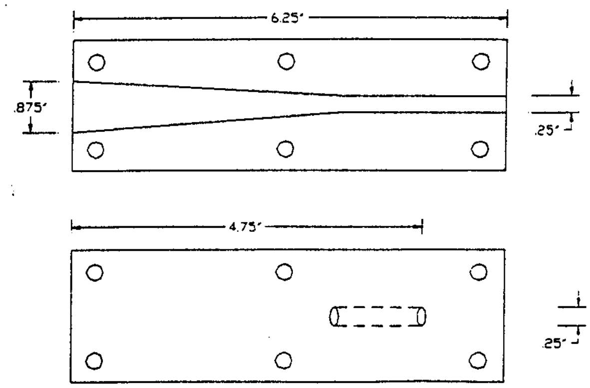

Figure 3. The Axial Venturi Type II Spreader

Figure 4. Stop-Action Spreading Photo

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